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Fish resource exploitation in the southern Atlantic coast of the Iberian Peninsula: A view from the traceological analysis of flaked stone tools (sixth-fourth mill. cal BCE)

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ABSTRACT

In this paper, we provide new data on fish resource exploitation during the Mesolithic and Neolithic period on the Atlantic coast of the Iberian Peninsula. Evidence from four different sites is presented: Vale Marim I (end of the seventh/beginning of the sixth millennium cal BCE) and Vale Pincel I (2nd and 3rd quarters of the sixth millennium cal BCE), both located on the southwestern Portuguese coast, and La Esparragosa and SET Parralejos (fourth-third millennia cal BCE), both located on the southern Spanish coast. The analysis of the lithic assemblages by means of use-wear analysis provided evidence of fish-processing activities. The analysis of the archaeological tools has been based on a renewed experimental framework for fish-related use-wear traces. Despite data being still scarce and fragmentary, this study points out the necessity of a more integrating approach, including traceological analysis in the framework of a broader research on prehistoric fishing.

1. Introduction

The Mesolithic-Neolithic transition in the southwestern Iberian Peninsula has been widely debated during the last decades (Carvalho, 2002, 2018; Soares and Tavares, da Silva, 2004; Ramos, 2005; Ramos et al., 2006; Cortés et al., 2012; Diniz and Neves, 2018). In this area, the first Neolithic populations largely settled in enclaves located in areas previously occupied by Mesolithic hunter-fisher-gatherer groups that depended on a broad range of coastal and terrestrial resources (Valente and Carvalho, 2009; Bicho et al., 2010; Ramos et al., 2011; Cortés et al., 2012; Soares and Tavares da Silva, 2018). Around 5500-5000 cal BCE, in southern Portugal Neolithic communities began a farming economy based on the exploitation of domesticated plants and animals, with ovicaprids and free-threshing wheat being the most frequent domesticated species in the archaeological record (Carvalho et al., 2013; Peña-Chocarro et al., 2014; Davis and Simões, 2016; López-Dóriga, 2015; Soares et al., 2016). Soon after the appearance of Neolithic complexes, Mesolithic presence in the area would rapidly decline for reasons still largely unknown. Much of the debate has been focused on the relationship between the Mesolithic and Neolithic communities, in terms of process of demographic absorption (Carvalho, 2002; Bicho et al., 2017), process of acculturation (Gonçalves et al., 2008), cultural osmosis (Tavares da Silva and Soares, 2007), and process of technical transfers (Marchand, 2005; Marchand and Manen, 2010). In this context, patterns of subsistence and, in particular, the dependence on marine and estuarine food sources has often been called into question as one of the key elements for understanding the Meso-Neolithic transition. While some scholars have pointed out a clear break in the subsistence systems between the two periods (Zilhao, 2003; Cortés et al., 2012; Dean et al., 2012; Carvalho, 2018), others defend a more nuanced transition and the existence, at least on some sites, of a continuity in the modes of resource exploitation (Soares, 1996; Ramos et al., 2006, 2011; Bicho et al., 2017). This would be especially true for shellfish and fish species. Nevertheless, one of the main limitations of

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such approaches is the limited amount of data on fishing practices of Meso-Neolithic populations. While shellfish exploitation is rather well known thanks to the abundant research on Mesolithic and Neolithic shell middens (Soares, 1996; Soares et al., 2005–2007; Soares, 2013; Bicho et al., 2010), available data on fishing practices is much scarcer (LeGall et al., 1992; Marques-Gabriel, 2015). Archaeological evidence of fish consumption and exploitation are indeed more rarely and discontinuously detected, due to problems of remains preservation and recovery. It is therefore very difficult to evaluate patterns of continuity or discontinuity relying on such fragmentary record.

One way to fill these gaps of the record could be to focus on the technology associated to fish exploitation and consumption. The presence of artefacts associated with fishing practices is a good indicator that can complete or even provide an alternative evidence of fishing when fish remains have not been recovered or preserved. Hooks, harpoons and fragments of fish traps represent a good example of these types of artefacts and a very clear testimony of fishing (Moundrea-Agrafioti, 2003; Marijanović, 2009; Komšo and Čuka, 2014; Clemente-Conte et al., 2013; 2016; Lozovski et al., 2013). Spatulas and other bone tools can also be associated with fishing or to fish processing activities, even if their recognition as fishing gear is far more complicated (Clemente-Conte et al., 2002; Rodríguez Santana et al., 2008; Arrighi et al., 2016).

Flaked stone tools can as well provide information on this topic. Pioneer experimental studies demonstrated that use-wear traces from fish scaling and processing presented characteristic features (Moss, 1983; Gijn, 1984/85/86), distinguishable from other use-wear categories such as butchering, bone or hide working. Successive experimental works confirmed that use-wear traces from fish processing could be quite distinctive (Clemente-Conte et al., 2010; García Díaz and Clemente-Conte, 2011). More recently, an integrated approach of use-wear and protein residue analysis has as well provided interesting results for Scandinavian lithic assemblages (Högberg et al., 2009), while a brand recent experimental approach through FTIR microspectroscopy (Monnier et al., 2018) suggests that this technique can also provide insights into fish processing tools, despite its archaeological applicability still has to be proved.

The aim of this article is to provide additional data on the Meso-Neolithic subsistence practises in the southwestern Iberian Peninsula, through the use-wear analysis of flaked stone tools. The study of coastal prehistoric societies led us to a revaluation of the methodological framework for interpretation of stone tool function. Therefore, basing on recent experimental works, a review of the available knowledge on fish-related use-wear traces will be provided. The results of the analysis of several flaked stone assemblages will be therefore presented. The sites taken into analysis are: Vale Marim I (Late Mesolithic) and Vale Pincel I (Early Neolithic) both located in the Alentejo Coast (Portugal), and La Esparragosa and SET Parralejos (Middle Neolithic) in the Bahia of Cádiz (Spain) (Fig. 1). The contribution of traceological analysis is especially relevant in those contexts in which the conservation of organic remains is generally poor, making difficult obtaining data on palaeoeconomic behaviours.

2. Materials and methods

Traceological analysis has been carried out with a stereoscopic microscope Leica AZ16 (10 × -60 ×) and a reflected-light microscope Leica DM2500 (50 × -400 ×), following a standard procedure. Archaeological tools have been cleaned with alcohol before the analysis. Experimental tools, after their use, were cleaned with water and alcohol, and afterwards with a solution of 1% hydrogen peroxide and placed in the ultrasonic tank to remove the most superficial residues.

2.1. *Archaeological sites and studied samples*

2.1.1. *Vale Marim I*

The site of Vale Marim I has been discovered and excavated by Tavares da Silva and Soares in the early 1980s. It is located in the Sines harbour domain (southwest Portuguese coast, Alentejo region). Excavation works revealed a high concentration of dwelling structures, and flaked stone remains. The site is interpreted as a large base camp, occupied almost all year-round (Soares and Tavares da Silva, 2018). Flaking activities and artefact production probably played a major role in this site (Soares et al., 2017). Site occupation has been dated to the Late Mesolithic thanks to a series of radiocarbon dates on charcoal samples that calibrated to 2-sigma give the time span of 6075–5840 cal BCE.

2.1.2. *Vale Pincel I*

The site of Vale Pincel I is located on the southwest Portuguese coast, few hundred metres away from the above-mentioned Vale Marim I. It is as large open-air site, covering a surface of about 10 ha. Domestic structures of diverse functionality have been detected during the excavation works, suggesting the existence of large and stable human occupation (Soares et al., 2016). Impressed Ware with very scarce Cardial motifs, filiated in the Pré-Franco-Iberian Cardial Neolithic (see Guilaine, 2017: Fig. 6; Soares and Tavares da Silva, 1979: p. 24) had been recovered from the excavations. Traceological analysis has revealed the presence of sickle blades used for harvesting cereals (Soares et al., 2016). Occupational phases have been dated thanks to a series of radiocarbon dates on charcoal. The greater probability density for site occupation is given for the interval *ca.* 5640–5380 cal BCE (Tavares da Silva and Soares, 2015).

2.1.3. *SET parralejos*

The site of SET Parralejos is located in Vejer de la Frontera (Cádiz, Andalucía, Spain), at an altitude of 182 m a.s.l., in one of the last hills of the Subbaetic System. Its current distance from the coastline is of about 9.5 km. The site has been discovered in 2008 (Villalpando and Montañés, 2009), and until now two excavation campaigns have been carried out, in 2008–2009 and in 2012. The site is one of the many '*campos de silos*' that characterise Andalucía at the end of the Neolithic period. Over an area of about 3000 m^2, 59 pits have been documented of which 34 have been fully excavated (Villalpando and Montañés, 2016). Radiocarbon dating suggests an occupation between *ca.* 3520 and 3015 cal BCE.

2.1.4. *La Esparragosa*

The site of La Esparragosa is few kilometres away from the village of Chiclana de la Frontera (Pérez et al., 2005; Vijande, 2006, 2008; Ramos et al., 2008, 2010). It is situated on a plateau beside the Iro River, at about 30 m a.s.l. A surface of 40 × 10 m has been excavated in two campaigns (2002–2003). The site is characterised by the presence of eight pit structures and one burial. The silos are semicircular in shape with different sections, both bell-bottomed and cylindrical types, whose diameter varies between 1 and 1.20 m and with a depth of 1–1.40 m. These structures appeared filled with faunal and malacological remains, lithics and pottery fragments (Vijande-Vila et al., 2018). Four dates have been obtained from charcoal samples and two dates by TL from pottery associated with the burial, indicating an occupation between *ca.* 3020 and 2920 cal BCE.

3. Experimental framework

3.1. *Fish processing use-wear traces: insights from experimentation*

Several authors have referred to fish-related use-wear traces in their works. Semenov (1964), Keeley (1980) and Vaughan (1985), refer to experiments on fish processing, however, without detailing the

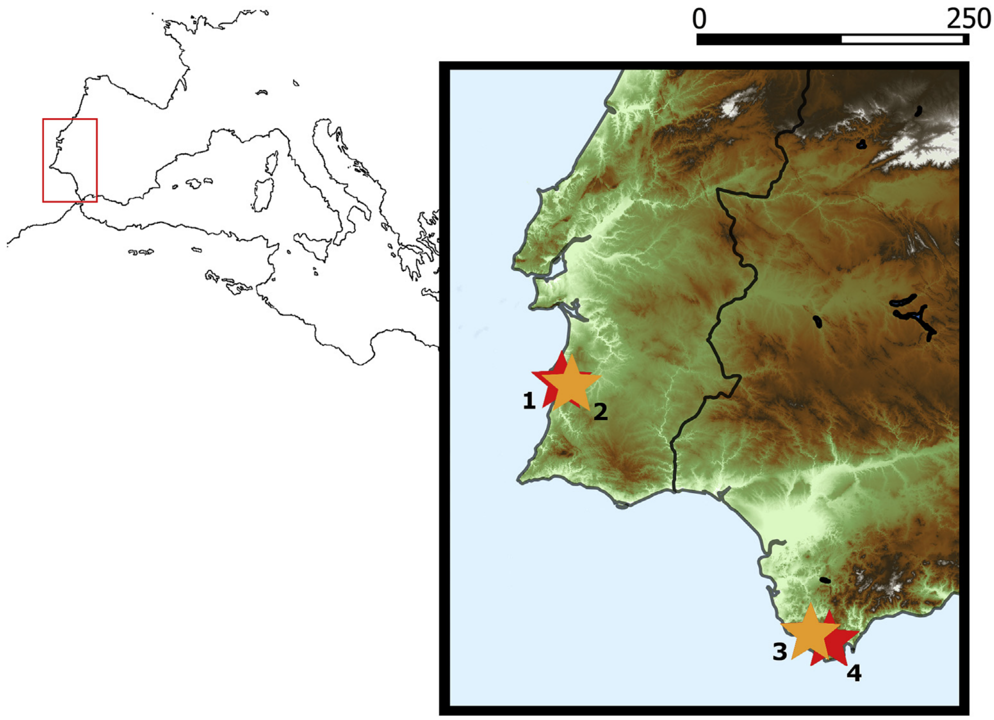

Fig. 1. Geographical framework. The stars indicate sites. 1) Vale Marim I; 2) Vale Pincel I; 3) SET Parralejos; 4) La Esparragosa.

microscopic and macroscopic features of this type of use-wear trace, including them within a broader category of 'meat' or 'butchering' use-wear traces. More detailed descriptions are provided by Anderson-Gerfaud, (1981), Moss (1983), Plisson (1985), Morin (2004), and Iovino (2002), and more recently Robson et al. (2018). Matt polish bands with striations are described as the main characteristic features. Nevertheless, the most detailed attempt to characterise use-wear traces from fish processing activities has been made by Gijn (1984/85/86, 1989). Different phases of fish cleaning and processing were reproduced separately: scaling, gutting and head cutting. The resulting traces were defined as following:

- Scaling: a dull and flat polish, characterised by rough and greasy appearance. The polish was often discontinuously distributed along the used edge. Only when the fish has very firm scales, a continuous and well-developed band of polish develops. Edge scarring if present, consists of irregularly distributed edge removal.
- Gutting: a rough, dull and flat polish. The polish is distributed in a more or less band near or somewhat behind the working edge, depending on the cases. Striations parallel to the direction of working movement are as well documented. An irregular scalar chipping of the edge is visible.
- Head cutting: a band of polish, dull and rough, is visible. Occasionally bright and smooth spots resulting from the contact with fish bone are observable. Edge scarring consists of a pattern of discontinuous fractures.

Within the framework of the current research, a new experimental program was carried out. The aim of this new experimental session was: 1) to corroborate previous experimental results; 2) to test the difference between hand-held and hafted tools; 3) to enlarge our experimental reference collection.

Seven different tools have been produced. All of them were made on a fine-grained chert of the Donbass Basin, microscopically similar to the chert exploited in the archaeological sites in study. Two elongated flakes and eight blades were used, all of them unretouched. Six tools were hand-held, while four blades were broken into fragments and hafted onto a straight wooden handle, forming a roughly straight cutting edge (Fig. 3). This hafting mode has been based on a hypothesis derived from the study of the archaeological materials, which often show reduced dimensions and would be more easily used hafted. Hafting allows as well to apply more pressure on the fish and thus cleaning tasks result more effective.

Small and medium size marine species were processed: striped red mullet (*Mullus surmuletus - Linnaeus, 1758*), common sole (*Solea vulgaris - Linnaeus, 1758*), European sea bass (*Dicentrarchus labrax - Linnaeus, 1758*), gilt-head sea bream (*Sparus aurata - Linnaeus, 1758*) and Atlantic pomfret (*Brama brama - Bonnaterre, 1788)*. The aim was to test the differences in the wear formation process. Although no differences were observed in the use-wear resulting from filleting, gutting and head-cutting tasks from different species, scaling traces developed more quickly when working gilt-head sea bream, a species with more resistant scales.

Twenty-three tasks were carried out at different time intervals (10, 15, 30, 45 60, 90 min) (Table 1). After each time interval, lithic edges were observed to document the process of wear development. In some cases, tasks were carried out singularly (eight for gutting, nine for scaling and three for decapitating). However, three tools were used to carry out the whole process (scaling, gutting, and decapitating), as it would seem archaeologically sounder to use the same tool for the entire cleaning process.

Results fundamentally confirm the description already made by previous authors:

- Scaling: use-wear traces are mainly formed on the face in contact with the fish scales, while micro scarring mainly occurs on the opposite face. Edge rounding is moderate, while micro polishes are characterised by a rough and greasy appearance, adapted to the topography of the flint (Fig. 2, C&D; Fig. 3, F).
- Head cutting: use-wear traces are equally formed on both sides, as the angle of contact between the working edge and the material is roughly perpendicular. As a result of the contact with the skeletal parts of animal, the polish appear rather flat, compact, forming a band along the edge, not penetrating into the inner surface (Fig. 2,

Table 1
Overview of the experimental works carried out. Seven different experiments, corresponding to 14 different actives zones were realized.

TOOL_NUMER	TOOL_TYPE	HAFTING MODE	ACTIVE ZONES	FISH SPECIES	ACTIVITY	TIME
EXP_1	Unretouched elongated flake	Hand-held	1	Gilt-head sea bream (*Sparus aurata*)	Head cutting	5
						10
						15
			2		Scaling	15
						30
						45
						60
EXP_2	Unretouched blade	Hand-held	1		Filleting and gutting	15
						30
						45
EXP_3	4 unretouched blade fragments	Hafted in a straight wooden handle	4		Mixed movement	60
EXP_4	Unretouched blade	Hand-held	1	Common sole (*Solea vulgaris*)	Mixed movement	90
EXP_5	Unretouched blade	Hand-held	1	Striped red mullet (*Mullus surmuletus*)	Mixed movement	60
EXP_6	Unretouched blade	Hand-held	1	European sea bass (*Dicentrarchus labrax*)	Filleting and gutting	15
						30
						45
			2		Scaling	15
						30
						45
			3		Gutting	5
EXP_7	Unretouched flake	Hand-held	1	Atlantic pomfret (*Brama brama*)	Scaling	10
						30
			2		Filleting and gutting	15

F; Fig. 3, E, H). However, a greasy polish with a less compact distribution might as well occur, in the interior areas.
- Filleting and gutting: both filleting and gutting show quite similar traces. They produce a combination of polish characterised by a rough and greasy appearance (produced by the contact with meat and skin parts) and spots of more compact and flat polish (produced by the contact with bone parts). Fine striations in the inner surface often occur because of the contact with fish vertebrae during gutting phases (Fig. 2G and H; Fig. 3A–E & G).

All performed tasks show quite similar traces, although subtle differences can be remarked. Tools that were used to carry out all the different steps show a combination of the various use-wear traces; in our option, it is very difficult to distinguish the traces produced by each individual task, especially in archaeological specimens. Nevertheless, at a more general level, fish traces appear quite distinctive because of the combination of their wear patterns, and should be separated from butchering and meat cutting use-wear traces.

4. Results

4.1. Archaeological evidence

4.1.1. Vale Marim I

The traceological analysis has been carried out over a relevant sample of flaked stone tools. 1213 artefacts have been analysed from a total assemblage of 7614 flaked lithics on chert raw materials. Stone knapping is locally carried out using nodular chert-types available in the regional context. All stages of core reduction are well-represented on site, and a bladelet-oriented production has been recognized (Soares et al., 2017).

The traceological analysis has revealed a low ratio of used tools. Of the analysed sample, only 132 used edges have been detected, which means a high percentage of unused edges. This pattern is not a result of bad preservation conditions; lithic edges and surfaces show very good state of preservation. Vice versa, the obtained data fit the hypothesis of Vale Marim I being a production centre. Flaking activities might have taken place during intervals of downtime in anticipation of a specific peak period of resource exploitation (Kuhn, 1989). In this sense, it is remarkable that an area specifically destined to knapping activities has been identified. Polished chisels, a concentration of flint cores and other artefacts have been recovered close to a hearth possibly used for chert heat treatment practises (Soares and Tavares da Silva, 2018). Among identified active zones (AUAs – Active Used Areas) (Fig. 4), there are traces of working processes on hard materials, such as wood, and antler/bone (25%, n = 33 AUAs). Use-wear traces are little developed, suggesting short duration tasks, eventually related to bone/wood tools maintenance and resharpening. Evidence of foraging and hunting practices has been obtained as well; several geometric projectiles (25%, n = 33 AUAs) show traces of having been used as tips. Finally, a large sample of tools, mostly bladelets, indicates the processing of animal carcasses (31.1%, n = 41 AUAs). Among them, 15 tools (11.4%, n = 15 AUAs) show a specific association of macro edge-rounding and scarring with greasy micro polish of irregular distribution and longitudinal striations (Fig. 5) that resemble the traces experimentally obtained by fish cleaning and processing. Those bladelets have an average width of 7.3–9.6 mm and an average thickness of 2.5–3.5 mm; blanks are unretouched, and acute angles are mostly selected.

4.1.2. Vale Pincel I

The technological and use-wear analysis has been carried out on a sample of 217 knapped chert artefacts from the lower layer of Vale Pincel I deposit (C. 2B) (Soares et al., 2016). This sample represents about the 17.4% of the whole chipped stone assemblage from the same area (1247 remains). The Vale Pincel I lithic assemblage shows a good state of conservation and more than a half of analysed samples presented well-preserved use-wear traces. The observed used zones (AUAs), reveal that a varied range of productive processes took place at the site, including tools associated with the working of mineral substance (4.7%, n = 6), hunting (13.2%, n = 17), and the obtaining and processing of plant raw materials (26.4%, n = 34). Among these latter, the most represented activity is cereal harvesting (24%, n = 31). However, the majority of tools are related to the processing of soft substances (44.2%, n = 57), related to animal carcasses butchering and cleaning. Among them, at least eight tools (6.2%) that present a very good preservation of the micro-traces have probably been employed for fish processing activities (scaling, decapitation, gutting) (Figs. 4 and 5). Used blanks are mainly bladelets, quite standardized in size and shapes (25–35 mm length, 8–12 mm width, 3–4 mm thickness).

4.1.3. La Esparragosa

The traceological analysis has been carried out on a sample of items

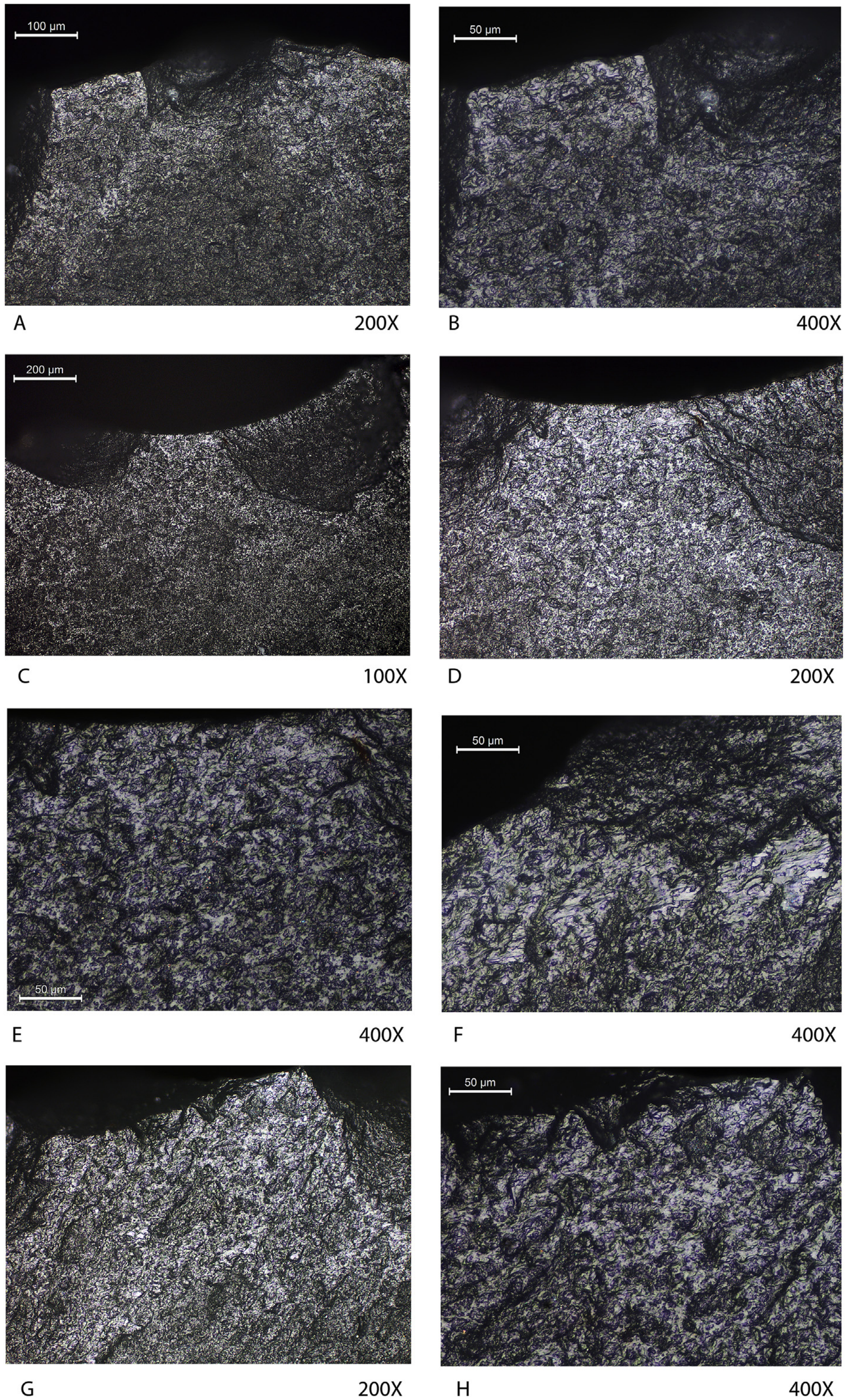

Fig. 2. Experimental use-wear analysis on lithic tools, between 100 × and 400 × , after cleaning six gilt-head sea bream, 100 × . A) Greasy and rough polish, 200 × . See how the polish penetrates inside the edge-fracture. B) Same polish. Spots of contact with fish bone 200 × . C) Band of greasy and rough polish along the edge, 100 × . See how the polish penetrates inside the edge-fracture. D) Same polish, 100 × . Note the greasy and rough appearance. E) Same polish, 400 × . F) Striation of contact with bone material, 400 × . G-H) Greasy and rough polish along the edge, 200 × and 400 × .

from the excavations campaigns of 2002–2003. Lithic production is characterised by a blade-oriented technology, including indirect percussion, pressure, and lever pressure (Morgado and Pelegrin, 2012). The analysis was focused on 388 lithic artefacts. Of them, about one half is composed of blades and blade fragments. Flake blanks represent about the 26%, while the remaining remains are composed of cores, and fragments of polished tools. Microscopic observation has revealed use-wear traces on 30% of the sample, for a totality of 164 AUAs. Wood working and cereal harvesting activities are well represented (14.2%, n = 24), followed by working tasks on hard (10.7%, n = 18) and mineral materials (1.8%, n = 3), as well as projectiles (3%, n = 5). Nevertheless, the majority of active zones (70.4%, n = 119) have been

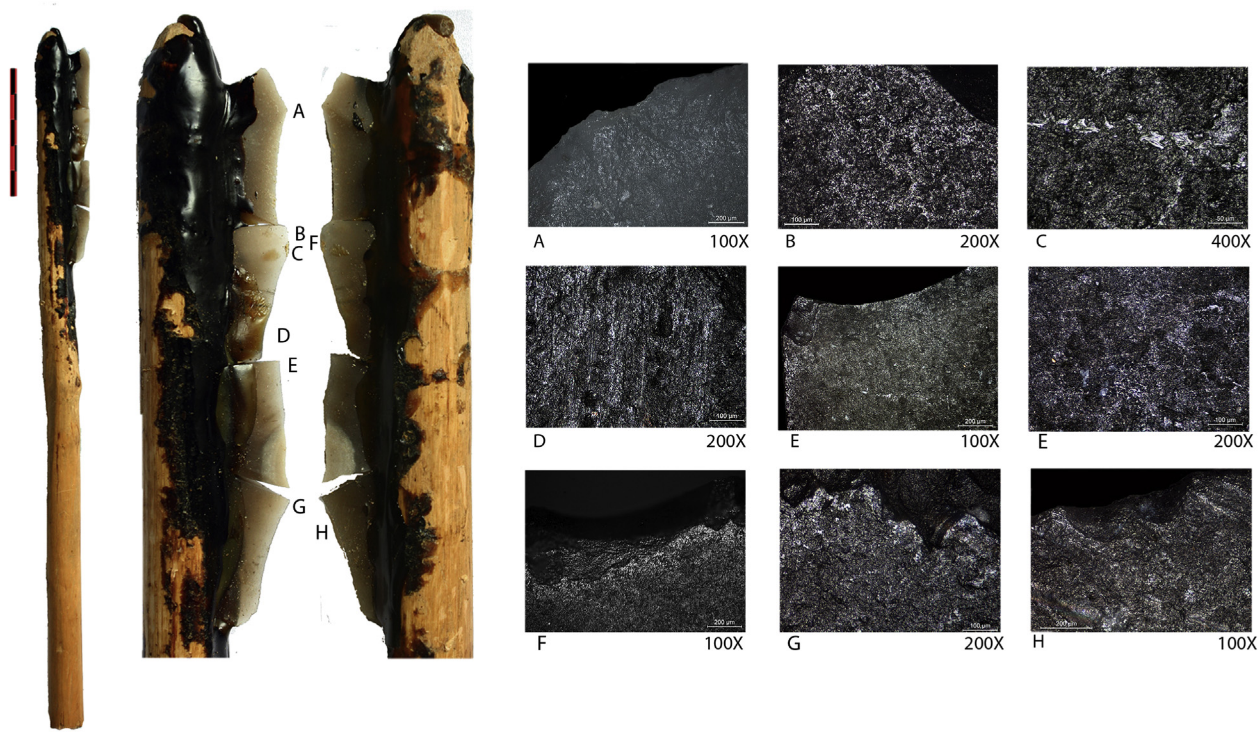

Fig. 3. Left. Experimental knife used for cleaning fish (scaling, gutting and head cutting). Right. A-B) Edge-rounding and greasy polish associated with contact with fish meat, 100 × and 200 × . C) Striation located in the interior of the surface, associated with gutting tasks, probably produced by the contact with fish vertebra and rib bones, 400 × . D) Striations perpendicular to the edge, associated to fish scaling, 200 × . E-F) Fine striations parallel to the edge, associated to gutting and fileting tasks, 100 × and 200 × . F-G-H) Use-wear produced from the different tasks involved in fish processing activity: band of polish along the edge, and spots of contact with bone materials.

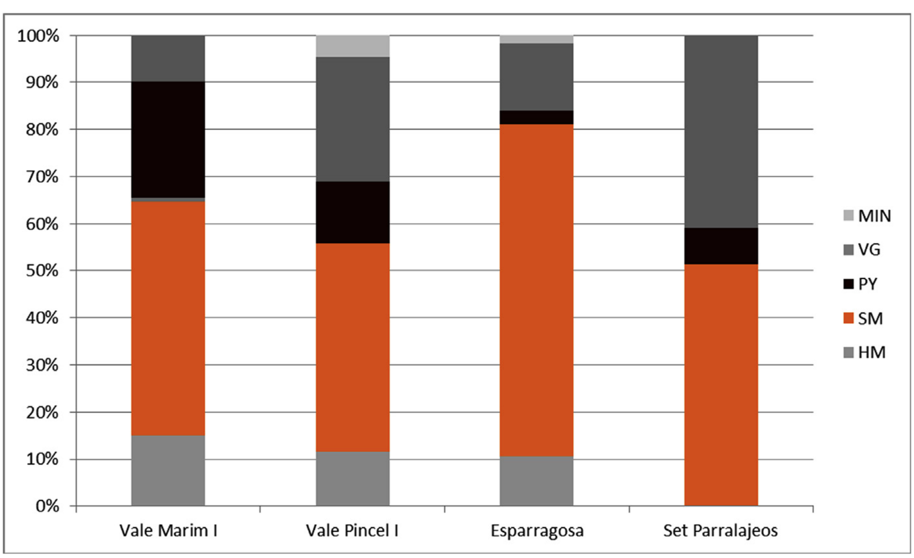

Fig. 4. Percentage of different type of use-wear recognized in the analysed assemblages. MIN: Working of mineral activities; VG: Processing and/or cutting of vegetal materials (plants, cereals, wood, etc.); PY: Traces on tools used as projectiles; SM: Cutting of soft materials, including fish; HM: Working of hard materials (bone/antler, hard indeterminate materials).

used processing animal substances, mainly using blade blanks. Among them, a very high percentage (80.6%) presents use-wear traces showing features close to the experimental traces obtained from fish cleaning and processing (Figs. 4 and 5) (Clemente-Conte and García Díaz, 2008; Clemente-Conte et al., 2013; Mazzucco et al., 2018).

4.1.4. SET parralejos

The analysis has been conducted on 54 items from various pit structures. The assemblage strongly resembles the Esparragosa lithic collections from a technological point of view. Analysed blanks are mainly blades and bladelets, and in lesser extent, flakes. Of them three are bifacial-retouched points. About one half of the assemblage has been excluded from the analysis given its poor preservation conditions, while use-wear traces have been individualised on the remaining 23 items, for a total of 39 AUAs. Identified tasks are mainly related to vegetal materials (41%, n = 16), of which cereal harvesting (38%) represents the main activity while only one tool is associated with wood working, to the processing of animal carcasses (51%, n = 20), and to projectile tools (7.7%, n = 3). Tools showing fish-polish amount to the 33% of the used tools (Figs. 4 and 5).

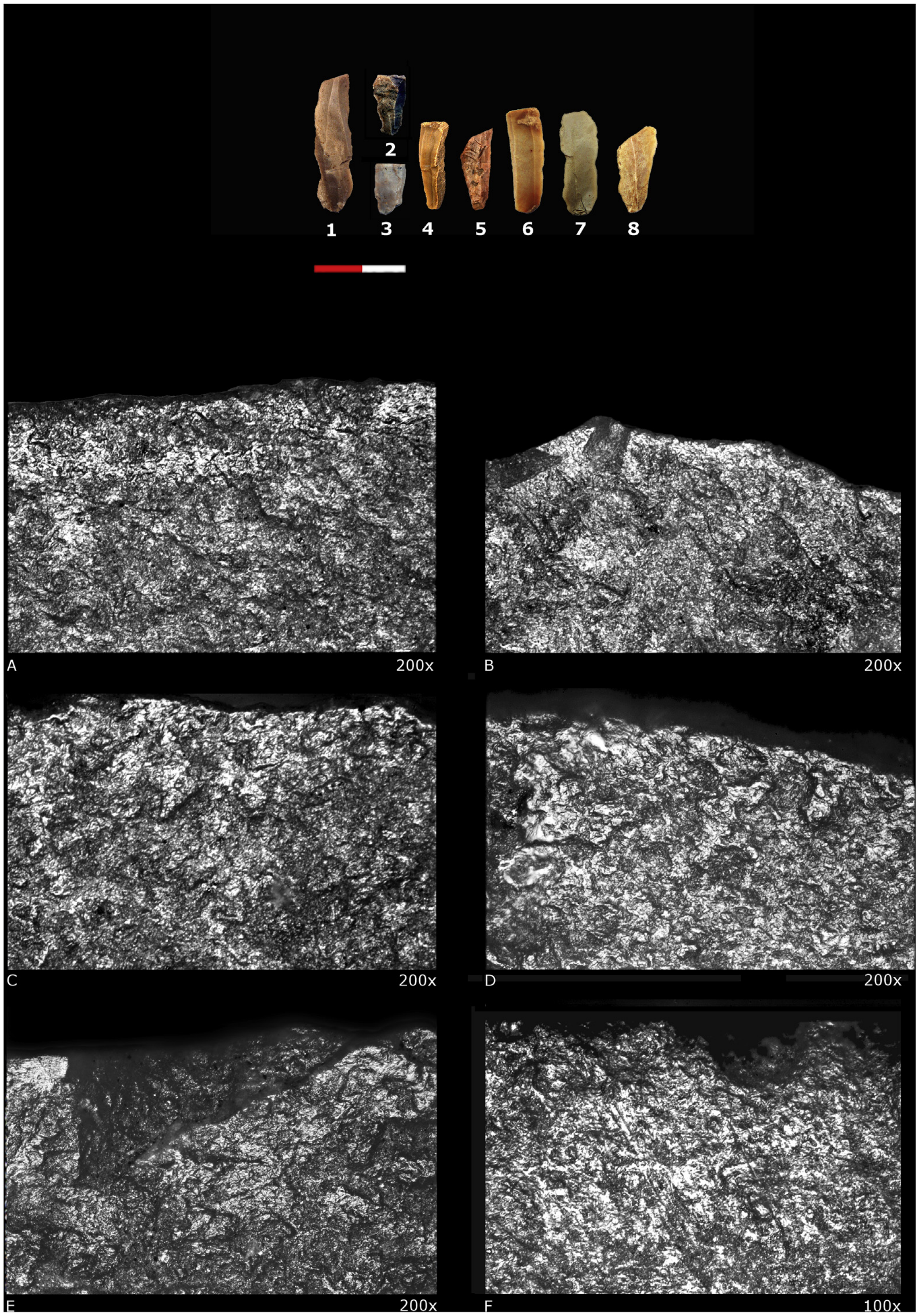

Fig. 5. Bladelets and fragments of bladelets from Vale Marim (1–5) and Vale Pincel (6–8). Lithic tools show well developed use-wears, showing feature similar to experimental traces from fish cleaning: striations and isolated spots produced by the contact with bone materials, associated to greasy and rough polishes, penetrating into the surface and within the edge-fractures. A-C) Use-wear traces from Vale Marim I, 100 × and 200 × ; D-F) Use-wear traces from Vale Pincel I, 100 × and 200 × .

5. Discussion

The experimental work carried out has allowed improving the definition of a category of use-wear traces that has often been overlooked by use-wear specialists. The difficulties with the interpretation of soft materials (i.e. meat- and fish-polish) have already been outlined by several authors and special caution should be taken when interpreting such category of use-wear (Gijn, 1989). Despite such limitations, in many archaeological contexts preservation conditions allowed significant insights into prehistoric butchering practices. Since the early years, traceological works have demonstrated that, in many assemblages, it is indeed possible to recognize use-wear from working soft substances thanks to the observation of a combination of both macro- and micro-wears (Plisson, 1985; González Urquijo and Ibáñez Estévez, 1994; Clemente-Conte, 1997 and more recent works). Therefore, there is no reason to suppose that while meat and butchering traces are

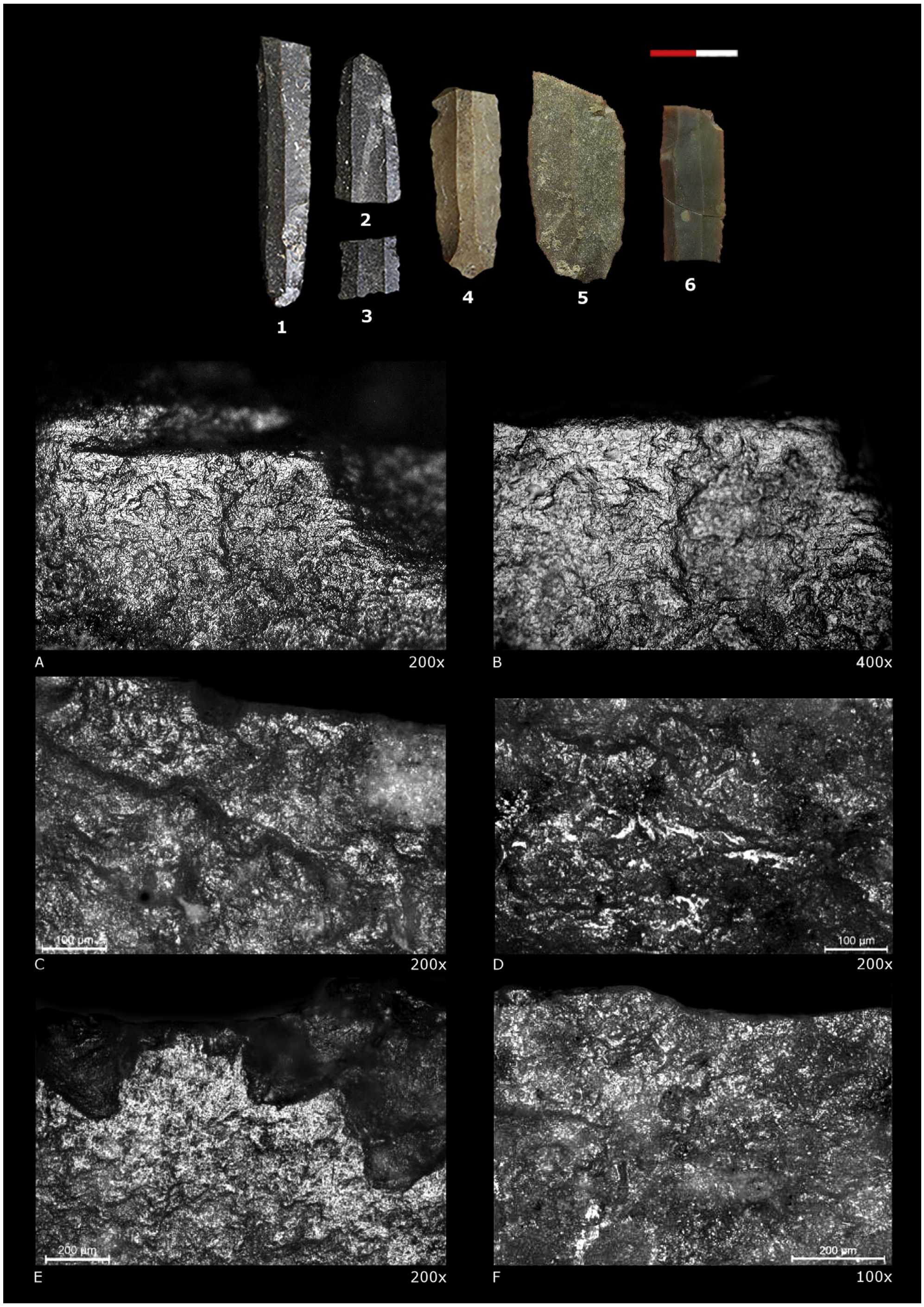

Fig. 6. Bladelets and fragments of bladelets from SET Parralejos (1–4) and La Esparragosa (5–6). Lithic tools show well developed use-wears, showing feature similar to experimental traces from fish cleaning: striations and isolated spots produced by the contact with bone materials, associated to greasy and rough polishes, penetrating into the surface and within the edge-fractures. A-B) use-wear traces from La Esparragosa, 100 × and 200 × ; C–F) use-wear traces from SET Parralejos, 100 × and 200 × .

recognisable in the archaeological specimens, fish-polishes are not.

The scarcity of fish-polish on tool assemblages from coastal prehistoric sites has been previously pointed out. There are in fact very few archaeological cases of fish-related use-wear traces, despite their distinctive character (Moss, 1983). The explanation provided by van Gijn (1989) is that in many cases fish-polish might have been bidden among the bone-cutting implements, impeding the recognition of the specific character of the task carried out. In addition, the employment of lithic tools to clean and process fish is mainly related to its preparation for conservation and storage practises (i.e. drying, smoking, salting), while it might not be necessary for its direct consumption. Therefore, even when archaeozoological evidence of fish consumption is present, it might not imply the use of specific tools for its processing. In this sense, use-wear analysis not only can provide indirect evidence of fish exploitation, but as well of the modalities and the extent of it.

Such range of topics is particularly relevant in the framework of the research currently carried out on the Mesolithic and Neolithic societies occupying the southern Atlantic coasts of the Iberian Peninsula. Archaeozoology analysis has provided evidence for the exploitation of fish in this area, since the Mesolithic (Marques-Gabriel, 2015), and during the course of the Neolithic (Soriguer et al., 2002). Nevertheless, the sites here analysed are characterised by a low preservation and a low number of fish remains.

Regarding Vale Pincel I and Vale Marim I the scarcity of fish remains is likely due to conservation issues. Organic materials are not preserved on both sites, probably because of soil acidity. A few charcoals and archaeozoological remains, among which a gilt-head sea bream molar teeth, have been recovered only from a few closed structures, mainly hearths, in which depositional environment was probably less acidic. In relation to La Esparragosa and SET Parralejos, they are both pit-sites and occupational layers were not preserved. Fish remains were neither stored nor rejected in the pits and fish cleaning activities were probably performed elsewhere, closer to the sea.

Data on Meso-Neolithic fishing practices can be obtained from other sites of the region. Fish remains are for example well documented in the Late Mesolithic site of Samouqueira I (Sines, Portugal), about 10 km south of Vale Pincel I and Vale Marin sites (Soares and Tavares da Silva, 2018). Data suggests that Mesolithic fishing economy was based on a diversity of prey, big and small. Small sharks and rays (*Chondrichthyes* class) are dominant. Most of them are attributable to the *Triakidae* family (dog shark). There were also fish of the *Osteichthyes* class, mainly gilt-head sea bream (*Sparus aurata*). Other identified species were meagre or jewfish (*Argyrosomus regius - Asso, 1801*) of the *Sciaenidae* family. Osteological remains from *Serranidae* and *Scombridae* (e.g. mackerel - *Scomber scombrus - Linnaeus, 1758*) were also recognized.

At the Early Neolithic site of El Retamar, located in the Bahía de Cádiz, at about 15 km from La Esparragosa, abundant ichthyofauna remains have been documented. Seven different species have been recovered, including fish of the *Sparidae* family – among which gilt-head sea bream is dominant – and, in lesser extent, epipelagic fish species among which meagre and bluefin tuna. Fish remains are mainly associated to hearth structures, and the anatomical representation suggests that some kind of processing activities were performed on-site (Ramos and Cantillo, 2009; Cantillo et al., 2010).

The results obtained from the analysis of Vale Marim I, Vale Pincel I, La Esparragosa and SET Parralejos shed new light on the understanding of fish exploitation practises (Fig. 4). The presence of a relevant percentage of traces bearing the characteristic features of fish-polish suggests that fish were not only consumed on this site, but as well processed, presumably for its conservation and storage. Use-wear analysis reveals invisible data that otherwise would not easily emerge from the archaeological records, especially in southern European contexts.

In the Mediterranean area, differently from other geographical regions, fishing and fish exploitation are discontinuously documented. Some examples are the Mesolithic sites of Vela Spila in Dalmatia (Rainsford et al., 2014), Cave of the Cyclops (Moundrea-Agrafioti, 2003), and Franchthi Cave in Greece (Rose, 1995), Dos de La Forca in the Alpine region (Coltorti et al., 2009; Crezzini et al., 2014), Grotta dell'Uzzo in Sicily (Tagliacozzo, 1993). However, there is not clear agreement whether fish represented a diet supplement or a main food source, with data strongly varying from one site to another. In addition, in most of these contexts, it is difficult to assess whether fish was caught and either consumed without further processing or processed for storage. With the introduction of agricultural and herding practices during the Neolithic, the exploitation of marine resources in general, including fish, seems to diminish, and of fish as well, eventually favouring an occasional and small-scale exploitation of species which could be caught relatively easily from coastal waters (Rainsford et al., 2014). One of the clearest evidence for a specialised exploitation of fish, including fish processing and storage practises, is provided by the submerged Pre-Pottery Neolithic site of Atlit-Yam in the northern coasts of Israel (Galili et al., 2004). Unfortunately, in none of the above-mentioned sites traceological studies have been carried out on the stone tool assemblage, and therefore it is not possible to correlate archaeozoological evidence of fish processing with any specific tool-type.

The isotopic analysis point out as well for a reduced input of marine resources on the diet during Neolithic in the Mediterranean (Salazar-García et al., 2017, 2018). Regarding the Portuguese Atlantic coast, isotopic data indicates a dietary shift between Mesolithic and Neolithic, with divergent dietary choices even among coexisting hunter-gatherers-fishing and farming communities (Guiry et al., 2016). Nevertheless, the number of individuals analysed is still very low and geographically sparse, especially for the area concerned in this study.

Our study provides additional data in this sense, pointing out the existence of fish processing practices since the Mesolithic and continuing during the course of the Neolithic. Obtained data suggest that, in coastal areas, fish represented an important resource, exploited for its consumption, but also processed for its storage. Although the differentiation of fish-related from other butchering traces is not always easy, especially on archaeological materials, it has been possible to highlight a relevant percentage of tools showing traces interpretable as produced by fish working tasks. For Mesolithic and Early Neolithic, between 6% and 12% of the used zones are associated to fish processing, while for Late Neolithic percentages are even higher (over 30% of AUAs). This data seems to point out a continuity in subsistence practises, but our sample is still too scarce and the number of analysed sites too small to evaluate the importance of this activity on a broader economic and social perspective. Neolithisation dynamics might have followed a different path in this region in respect to other geographical areas where fishing and fish processing do not seem to play a relevant role (i.e. north-east of the Iberian Peninsula) (Mazzucco and Gibaja, 2018), even in sites located in coastal areas (Borrell and Gibaja, 2012). Other authors have already highlighted the existence of specific cultural and material features in the Neolithic of the southwestern façade of the Iberian Peninsula, confirming the idea of regionalisation or local recomposition of the Neolithic package (Manen et al., 2007). This process might be reflected as well in the adoption of different economic strategies, adapted to diverse local environmental and cultural conditions.

6. Conclusions and perspectives

Fish is an important resource, providing important vitamins, proteins, and minerals. It is a fairly reliable, renewable, and predictable food source. Its role in prehistoric societies is still largely unknown, and the interpretation of fishing remains controversial. Despite that, its importance at a dietary level might have been strongly varying from period to period, from area to area, and from site to site. Use-wear and residue analysis might represent additional techniques to approach such topic. Enlarging the number of studied contexts and refining the experimental and methodological framework it may be possible to open new perspectives for the study of fish processing and preparation techniques. In addition, in the framework of an ongoing project, we will try to approach fish-polish through confocal microscopy (Ibáñez et al., 2019), in order to quantitatively characterise their microtextural features and better separate them from other classes of use-wear traces, especially traces from butchering of mammals.

Chemical analysis of fat residues preserved in pottery vessels and archaeological structures are currently ongoing in the studied sites and will as well provide additional data on Meso-Neolithic cooking and food practises. In this sense, it is remarkable that at Vale Marim I, site excavators identified a domestic structure which contained *Sparus aurata* molar teeth and was composed of a fireplace within fire-cracked cobbles packed into sandy-grey sediment with traces of combustion remains, linked to a stoned posthole (Soares and Tavares da Silva, 2018). Despite the unfavourable conditions of organic materials preservation at the site, future analysis will explore whether this feature was related to fish conservation practises or not.

In conclusion, the role of fish resources should not be overlooked by archaeologists, despite information being often fragmentary, especially in the Mediterranean area. The study of fish-related practices (processing, storage, consumption, etc.) and of related tools, structures and residues undoubtedly represents an important field of research to be

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developed, integrating different sources and analytical methods.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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